Spatiotemporal agent-based modelling to analyze sustainability issues at the landscape level – The grazing herbivores metaphor

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Abstract: This model aims at simulating herbivores grazing in a rangeland landscape. The first aim is to find a balance between the herbivores and the vegetation dynamics guaranteeing sustainability: maintain a healthy animal population and a green landscape. Two opposite processes threaten this equilibrium: overgrazing, leading to desertification, reversible; under-grazing leading to shrub invasion, irreversible. Both processes may ultimately lead to the population extinction by starving and pasture invasion by shrubs. The model implementation with the NetLogo simulation platform (Wilensky, 1999) comprises two types of agents: "Patches" standing for land plots; "Turtles" standing for herbivores. Patches are characterized by their color: shades of green for grass, red for shrubs. Herbivores are characterized by attributes like birth date, age, previous location, destination, pathway, travelled distance, ingested feed, body weight, calving dates. During simulation each turtle iterates the following: find a destination, move, graze, gain and lose weight, age and, possibly, reproduce or die. Simulations have been made to check variants of the system's structure and behaviors based on a reference landscape comprising 1,225 patches (1 ha each) and 1,225 turtles standing for cattle (1 head/ha). Simulation assessment criteria are the herbage biomass, herbivore population size, individual body weights, birth and mortality rates, land-use patterns and landscape fragmentation obtained after a 5-year time period. The following issues have been explored by simulation experiments:

- Heterogeneity of landscape at initialization: starting with patches uniformly green or with different greens in a relatively narrow range makes almost no difference. However, with higher heterogeneity the system's performances decrease in terms of population size, pasture area and shrub extension. Homogenous landscapes become more heterogeneous and conversely. Whatever their initial state, all landscapes converge eventually towards the same heterogeneity degree.
- Heterogeneity of spatial distribution of animals at initialization: starting with all turtles located on the same patch leads to a quick resource depletion radiating in concentric circles around the origin with huge mortality. The remnants colonize a few peripheral patches where they stabilize at a very low level, abandoning the rest of landscape to shrub invasion.
- Graze as much as you can or preserve resource? The best strategy for all turtles proved to be: if grass on the current patch is above a certain height, then keep on grazing, otherwise move to another patch.
- Type of animal walks: directed walks (e.g. individuals move to patches with maximum herbage) tend to create excessive local density much higher than non-directed (random) walks, inducing overgrazing, high herbivores mortality and bushy patch extension.
- Length of elementary moves: among random walks, short moves (local foraging) are most likely to lead to animal wealth and herbage preservation than long ones. "Levy walks", alternating both moves, lead to intermediate results. Landscapes resulting from short walks are less heterogeneous. However, long moves, fostering quick animal distribution in space, are better to reduce local excessive densities and resource depletion. Introducing two breeds of herbivores endowed with different walks in the same ecosystem confirmed this conclusion: the short walk population takes over the long-distance one which may go to extinction because of over-mortality due to weight losses caused by excess displacements.

These findings are in accordance with both herbivores behaviour as well as cattle farmers' grazing management rules. If the emphasis has been put here on animal movement, which proved to be crucial in shaping the whole ecosystem, the model allows also one to explore issues linked to ecosystem complexity (adding other trophic levels), percolation (dissemination of products through space) and resilience (assessment of disturbances through time and space on animals and land). How far this "herbage-herbivores" model, basically featuring the interaction between immobile and mobile agents (i.e. patches and turtles), can be used as a metaphor to represent other kinds of systems will be discussed.

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